(12) UK Patent Application (19) GB (11) 2 269 968 (13) A

(43) Date of A Publication 23.02.1994

(21) Application No 9317050.4

(22) Date of Filing 16.08.1993

(30) Priority Data
(31) 9217313 (32) 14.08.1992 (33) GB

(51) INT CL^5
H04M 3/02

(52) UK CL (Edition M)
H4R RD RLS

(56) Documents Cited
None

(58) Field of Search
UK CL (Edition L) H4L LFND , H4R RD RLAS RLS
INT CL^5 H04B
ONLINE : WPI

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(54) Method and apparatus for attenuating an unwanted signal in a mix of signals

(57) Apparatus for attenuating an unwanted signal, eg. a speech signal, in a mix of signals, eg. a broadcast audio signal, includes an adaptive cancellation circuit 30 having an adaptive transversal filter 32 controlled in accordance with the circuit output. The apparatus is provided with a delay measurement system 10 for measuring the delay between the unwanted and mixed signals and for controlling the appropriate one of two variable delays 21 and 22 so as to approximately co-time the unwanted signal and the contribution of the unwanted signal which is in the mixed signal. The adaptive filter can thus be made significantly smaller.

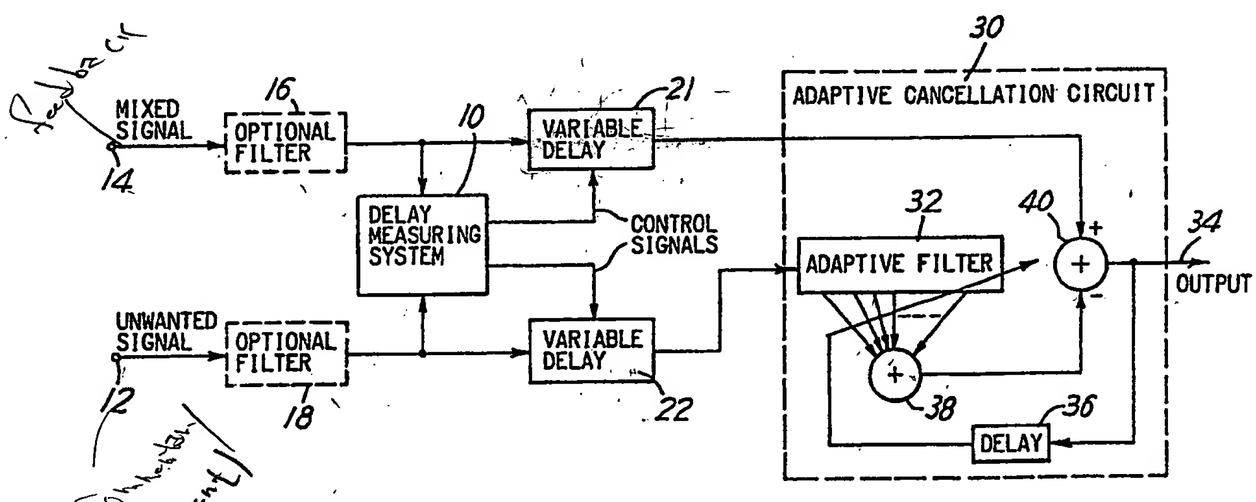

FIG.1

GB 2 269 968 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

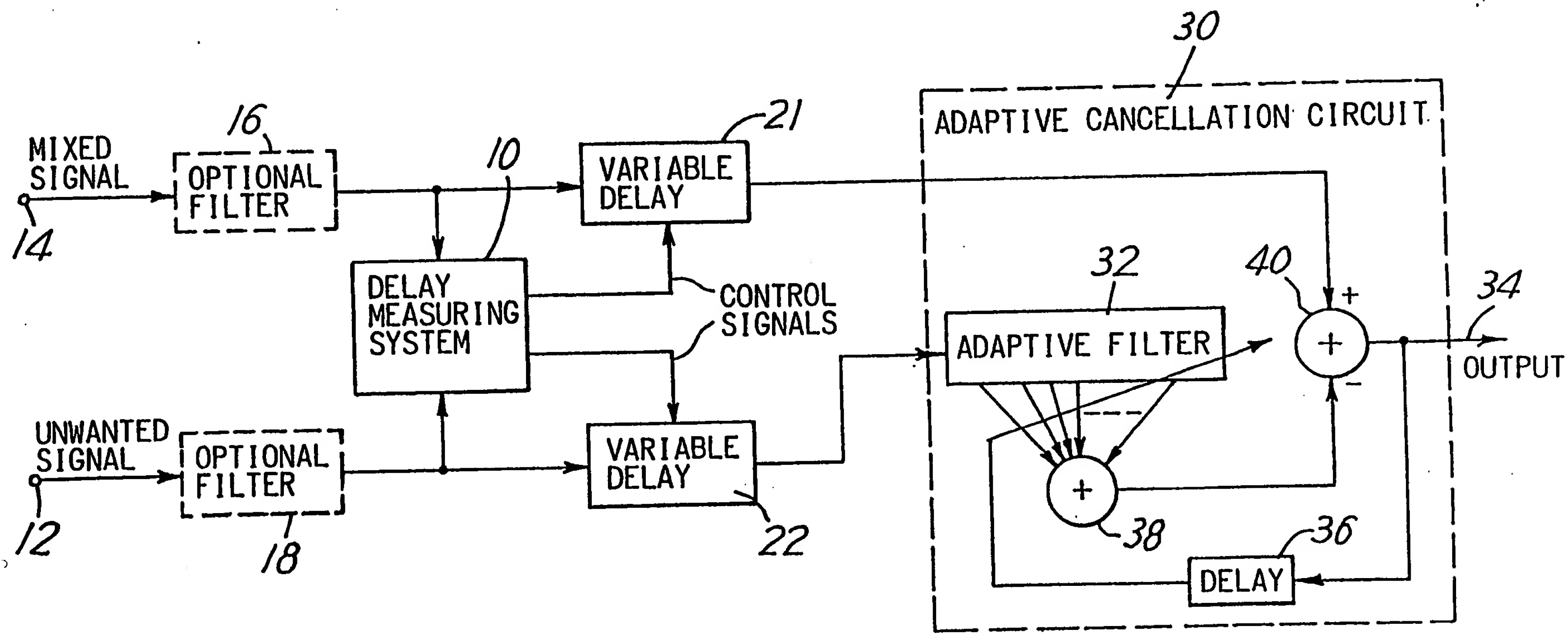
MIXED SIGNAL
14
16
OPTIONAL FILTER
UNWANTED SIGNAL
12
OPTIONAL FILTER
18
10
DELAY MEASURING SYSTEM
21
VARIABLE DELAY
CONTROL SIGNALS
VARIABLE DELAY
22
30
ADAPTIVE CANCELLATION CIRCUIT
32
ADAPTIVE FILTER
38
36
DELAY
40
+
-
34
OUTPUT

FIG. 1

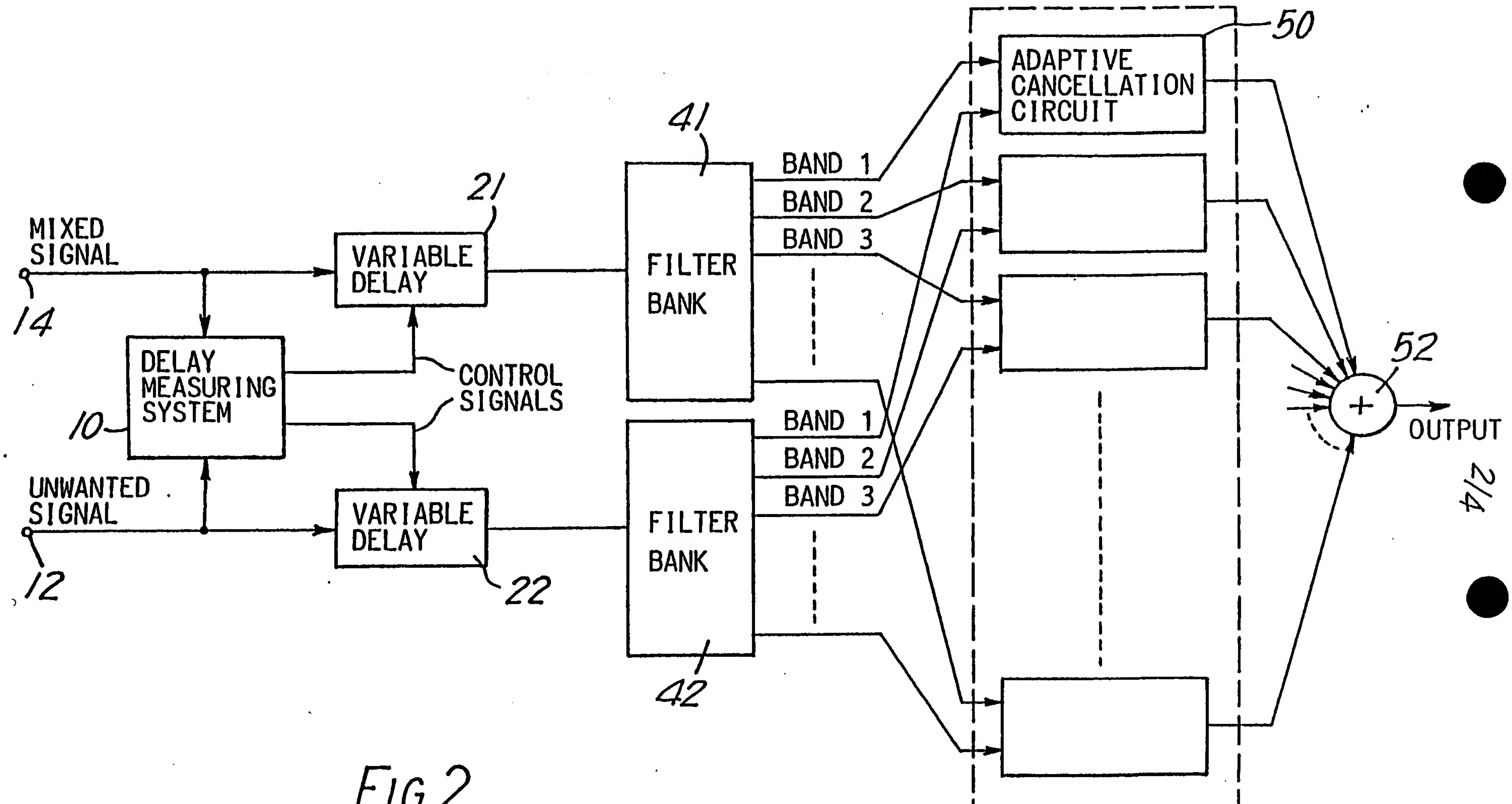
MIXED SIGNAL
14
UNWANTED SIGNAL
12
DELAY MEASURING SYSTEM
10
VARIABLE DELAY
21
VARIABLE DELAY
22
CONTROL SIGNALS
FILTER BANK
41
FILTER BANK
42
BAND 1
BAND 2
BAND 3
BAND 1
BAND 2
BAND 3
ADAPTIVE CANCELLATION CIRCUIT
50
52
OUTPUT

FIG. 2

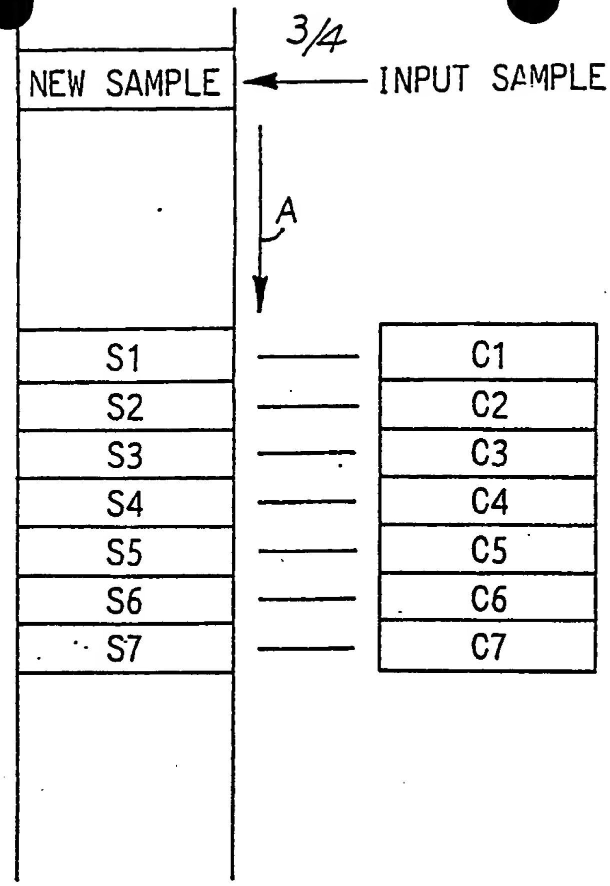
NEW SAMPLE
INPUT SAMPLE
A
S1
S2
S3
S4
S5
S6
S7
C1
C2
C3
C4
C5
C6
C7

FIG.3

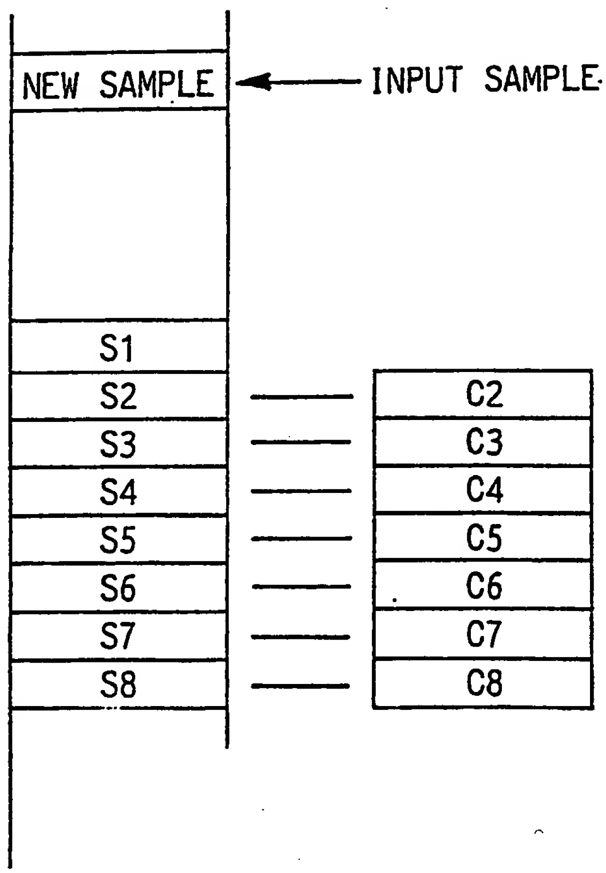
NEW SAMPLE
INPUT SAMPLE
S1
S2
S3
S4
S5
S6
S7
S8
C2
C3
C4
C5
C6
C7
C8

FIG.4

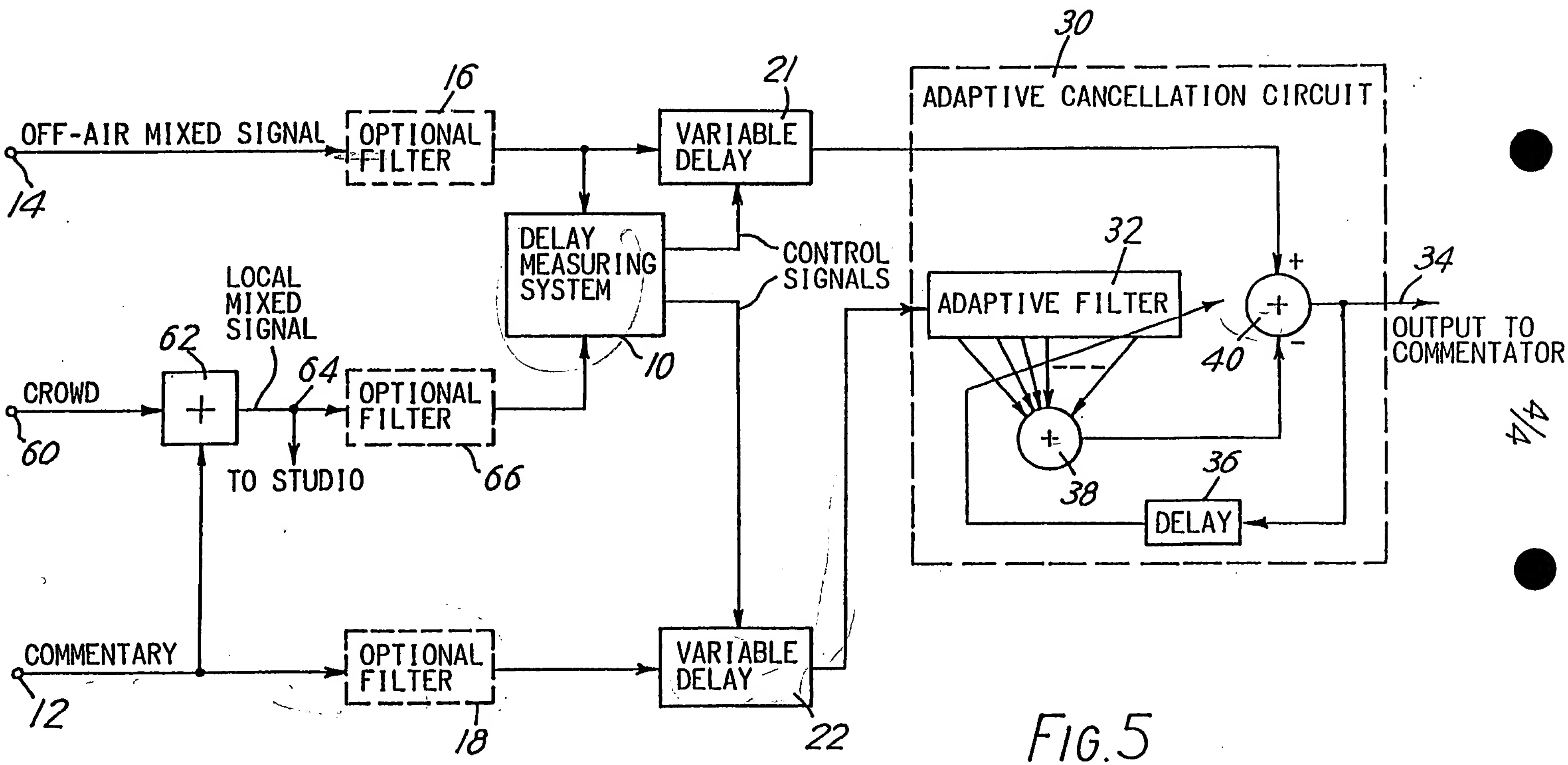
OFF-AIR MIXED SIGNAL
14
OPTIONAL FILTER
16
VARIABLE DELAY
21
DELAY MEASURING SYSTEM
10
CONTROL SIGNALS
CROWD
60
62
LOCAL MIXED SIGNAL
64
TO STUDIO
OPTIONAL FILTER
66
COMMENTARY
12
OPTIONAL FILTER
18
VARIABLE DELAY
22
ADAPTIVE CANCELLATION CIRCUIT
30
ADAPTIVE FILTER
32
38
DELAY
36
40
34
OUTPUT TO COMMENTATOR

FIG. 5

METHOD AND APPARATUS FOR ATTENUATING AN UNWANTED SIGNAL IN A MIX OF SIGNALS

FIELD OF THE INVENTION

This invention relates to a method and apparatus for attenuating an unwanted signal which is included in a mixed signal which comprises a contribution from the unwanted signal together with other signals.

This invention is particularly applicable to the fields of broadcasting and programme production, specifically to a method of removing an unwanted, given, audio component from a mix of signals, where the amplitude and time-offset of the given component in the mix are unknown and subject to variation.

BACKGROUND OF THE INVENTION

It is common practice to supply a commentator at an outside broadcast event with a feed of the off-air programme to provide a cue signal. An announcer or studio presenter usually leads up to the contribution and introduces the commentator as part of the broadcast programme. The commentator hears this cue in the programme received off-air and starts to speak. A problem which then manifests itself is that the commentator hears his or her own voice in the off-air feed with the delay incurred by passing through the broadcast chain. This has been known to be so distracting as to render the commentator speechless.

This phenomenon currently causes problems in television (TV) and radio operations. However when Digital Audio Broadcasting (DAB) is introduced the delays introduced in the broadcast chain could be of the order of 500 ms (half a second), and this will cause an extremely distracting effect even for an experienced commentator.

A solution to the problem would be to provide the commentator with a feed of the programme signal prior to the addition of his own commentary, i.e. produced locally at the outside broadcast site. For many operational reasons this is not feasible,

particularly when the programme has contributions from several sites, which the commentator would then not be able to hear.

The preferred solution to the problem would be to suppress the sound of the commentator in his personal feed of the programme which has been received off-air. As the commentary signal is available on its own at the originating site it can in principle be subtracted from the off-air feed, if it can be delayed by an appropriate amount and the correct gain applied to it to give cancellation in the off-air feed. In addition equalisation may have been applied to the commentary, either deliberately or as a consequence of being broadcast, and compensation may also have to be made for this.

Other instances may occur where it would be desirable to remove a component of a mix of signals, e.g. a mix of dialogue and sound effects. The dialogue alone is required. However if the sound effects are separately available, the clean dialogue could be recovered from the mix by subtracting them using the same techniques.

Removing intrusive background noise (for example air-conditioning or lift noise) from recordings could also be carried out in this way. If a separate recording were made of the interfering signal simultaneously with the desired signal then it would be possible to attenuate the interfering signal present in the final production.

Whilst these problems can be partially addressed by known signal processing techniques, as employed, for example, in an adaptive signal canceller, there are additional problems encountered where there is an unknown relative delay between the mixed signal and the unwanted signal and in particular where this delay may be varying. We have appreciated that a major limitation of other techniques in this situation is that the potentially large relative delay involved would necessitate a long filter length to give adequate suppression of the unwanted signal. This would result in a more expensive solution and would have the additional drawback of requiring a longer time to adapt to the signals and achieve the required suppression.

SUMMARY OF THE INVENTION

An object of this invention is to provide a method of removing a signal ("the unwanted signal") from a mix of signals ("the mixed signal") which includes the unwanted signal. Furthermore the amplitude and frequency equalisation of the unwanted signal in the mixed signal may be unknown and an unknown time-offset may exist between these two signals.

The invention in its various aspects is defined in the independent claims below, to which reference should now be made. Advantageous preferred features of the invention are set forth in the appendent claims.

A preferred signal attenuator, described in more detail below, includes an adaptive cancellation circuit having an adaptive filter which is controlled in accordance with the circuit output. The apparatus is provided with a delay measurement system for measuring the delay between the unwanted and mixed signals and for controlling one or more delays so as to approximately co-time the unwanted signal and the contribution of the unwanted signal which is in the mixed signal. The adaptive filter can thus be made significantly smaller.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail by way of example with reference to the accompanying drawings, in which:

Figure 1 is a block circuit diagram of a first signal attenuator embodying the invention;

Figure 2 is a block circuit diagram of a second signal attenuator embodying the invention;

Figures 3 and 4 are diagrams illustrating the operation of the attenuator of Figure 1; and

Figure 5 is a block circuit diagram of a modification of the attenuator of Figure 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiment shown in Figure 1 uses a combination of delay measurement and adaptive signal cancellation. The attenuator operates with digital signals sampled at a frequency of the order of 48 kHz. A delay measuring system 10, which can be based on phase correlation techniques, is used to measure the delay between the unwanted signal received at an input 12 and its contribution present in the mixed signal received at an input 14. The system 10 can be based on the method described in "The Phase Correlation Image Alignment Method", Kuglin CD and Hines DC, Proceedings of the IEEE, International Conference on Cybernetics and Society, September 1975, pages 163 to 165. The measurement of delay is then used to control two audio delaying devices 21 and 22, which receive the mixed signal and the unwanted signal, respectively, and which are adjusted to delay the leading signal in order to co-time approximately the two signals. After being co-timed in this way, the unwanted signal and the mixed signal are applied to an adaptive cancellation circuit 30.

The adaptive cancellation circuit 30 automatically corrects for any remaining small delays between the signals, and has a filter 32, which may take the form of a transversal filter, to filter the unwanted signal prior to subtracting it from the mixed signal. To this end the signal at the output 34 of the adaptive cancellation circuit 30 is applied through a delay 36 to control the coefficients of the filter 32. The filter 32 is provided with a combining circuit 38, the output of which is applied to the inverting input of a subtractor 40 which receives the delayed mixed signal at its non-inverting input. The output of the subtractor 40 constitutes the circuit output 34.

This cancellation circuit 30 is adaptive and modifies its own operation in a conventional manner to minimise the level of the reference signal remaining in the mixed signal. The well-known LMS (least mean squares) adaption algorithm has been found to be satisfactory for this purpose although other techniques could be applied. For further details of adaptive signal cancellation reference may be made to the textbooks "Adaptive Signal Processing", Widrow, B. and Stearns, S.D., published by Prentice-Hall, 1985, ISBN

0-13-004029-0, see especially pages 302 - 306, and "Theory and Design of Adaptive Filters", Treichler, J.R., Johnson, C.R., and Larimore, M.G., published by John Wiley and Sons, 1987, ISBN 0-471-83220-0, see especially pages 229 - 233.

The use of an audio delay measurement system 10 and delays 21, 22 in this way allows a shorter filter 32 to be used in the adaptive canceller 30 which consequently reduces its cost and also ensures that the adaption operation is rapid and responsive to changes in the signals.

The system can be further improved by filtering the mixed and unwanted signals to eliminate components of the signals which are outside the frequency band of interest. Such filters are shown at 16 and 18 in dashed lines in Figure 1 and may be placed before or after the delays 21, 22. For example, the presence of DC components, which could be introduced by mis-aligned analogue-to-digital conversion equipment, can lead to poor suppression of the unwanted signal in the band of interest. By removing these components prior to the adaptive canceller 30 the suppression of the unwanted signal in the frequency band of interest is improved. Similarly, higher frequency components may be filtered out by band-pass or low-pass filters to ensure that the operation of the system is not perturbed by other elements of the signals which are not of concern.

In order to cope with the situation where more severe phase or amplitude effects are being introduced, perhaps by filtering as part of the broadcast chain, it may be beneficial to employ several adaptive cancellation circuits operating in parallel as shown in Figure 2. In this arrangement two identical filter banks 41 and 42, or similar units, are employed to split the mixed and unwanted signals into several separate frequency bands, and are located after the delays 21, 22 to avoid the need to duplicate the delays. Each of the plurality of cancellation circuits 50 processes one of the frequency bands, and their outputs are summed in an adder 52. The advantage of this approach is that better suppression of the unwanted signal can be achieved in each of the individual bands where the filtering requirements of each band are significantly different.

A further problem arises when the delay through the broadcast chain is varying, as would be the case when the broadcast signals are passed through re-synchronising systems typically employed in broadcast centres. These devices co-time video signals by inserting a variable delay in the paths of the video and audio signals. This delay will vary depending on the instantaneous relative timing of the incoming video signal and the reference to which it is to be synchronised. In order to cater for this situation the delay measurement system 10 may be used to monitor changes in the relative delay of the mixed and unwanted signals. Small variations in this delay are of no concern as these are eliminated by the adaptive canceller. However, as the relative delay increases further, the adaptive canceller 30 will move towards one end of its range as imposed by the hardware implementation, i.e. the adaption will "move" the centre of the filter along the filter hardware, reducing its effectiveness as it nears one end. For extreme variations in relative delay the adaption will attempt to move the filter beyond the end of its range and the required cancellation will not occur.

This problem is overcome by using the delay measuring system 10 to vary the compensating audio delays 21, 22 as changes in the relative delay of the incoming signals are detected. When small changes in delay are detected the system makes no compensation adjustment until the aggregate of these changes may affect the effectiveness of the adaptive canceller 30. At this point the compensating audio delay could be changed inaudibly to match the new delay value and centre the adaptive canceller at the mid-point of its range.

An alternative method can be employed when the delays 21, 22 and adaptive canceller 30 are implemented together and share the same signal storage elements. It will be recalled that the adaptive filter 32, being a transversal filter, comprises a series of one-sample delays arranged to provide simultaneously a sequence of adjacent sample values, multipliers for multiplying the sample values by respective filter coefficients, and combining circuits for adding the outputs of the multipliers. In the alternative method the delays 21, 22 together with the delay chain in the adaptive

filter are all constituted by a single large area of memory.

The method is illustrated diagrammatically in Figures 3 and 4. Figure 3 shows the operation of the delay and adaptive canceller prior to a change in delay being required. In this case the filter within the canceller is operating on samples S1 to S7 using adaptive canceller coefficients C1 to C7 respectively (in practice a longer filter length would be employed). Arrow A indicates the direction of effective movement of the samples through the delay and filter memory. Figure 4 illustrates the situation when an increase in overall delay has been detected, and shows the new adaptive canceller coefficients. In this case the start of the window of samples used by the filter is moved from S1 to S2 and the start of the coefficients is similarly moved to C2. The result of this change is that sample S1 and coefficient C1 are no longer used, but sample S8 and new coefficient C8, which is initially set to zero, are now included. Thus the sample and coefficient pairs remain in the same relationship, S2-C2, S3-C3 etc., as before, to minimise any instantaneous disturbance to the output signal as a result of the change. However the overall effect is to move the position of the adaptive canceller within the delay and hence maintain it within its operating range. The new coefficient, in this example C8, although set initially to zero, will be adapted by the canceller as necessary to re-establish the optimum suppression under these new circumstances. This operation of moving the adaptive canceller through the samples within the delay can continue until the correct operating delay for the new situation has been achieved.

Figure 5 shows a slight modification of the arrangement of Figure 1, and is described in the specific context of an outside broadcast commentator who is commentating on a sports event. As with the Figure 1 system, a feed of the off-air mixed signal is received from the studio as a cue signal at input 14, and the commentary from the commentator's microphone is received at input 12. The output 34 is supplied to the commentator's headphones.

A background signal comprising the outputs of other microphones at the event, which may conveniently be referred to as a "crowd" signal, is received at an input 60, and is combined with the

commentary in a combining circuit 62. The output 64 of the combining circuit 62 constitutes the output from the outside broadcast event and may be termed the locally-orginated mixed signal. This signal is fed to the studio.

In the arrangement of Figure 5, the delay measuring system 10 receives the mixed signal from input 14, but instead of receiving the commentary alone from input 12, receives the locally-originated mixed signal from output 64 of the combining circuit 62. An optional filter 66 may be included similar to the filter 18. The delay measuring system 10 provides an output to control the variable delay 22 which receives the signal from input 12 as in Figure 1.

This arrangement works similarly to Figure 1, and retimes the commentary signal so it can cancel the component in the mixed signal feed. However, it allows the delay measurement to be carried out as soon as the locally-originated mixed signal is broadcast. It is not necessary for the system to wait until the commentator starts speaking before it can measure the delay, as in Figure 1. It can therefore achieve more rapid cancellation of the unwanted signal.

The modification shown in Figure 5 can also be used in conjunction with the system shown in Figure 2.

By employing the technique described the systems illustrated are able to track large variations in the relative delay between the applied signals without requiring a large filter in the adaptive canceller 30, consequently avoiding the longer adaption times which would result. If only the adaptive cancellation circuit were used, to accommodate a delay of 500 ms would require 24,000 multipliers and associated combining circuits in the transversal filter 32. By using one of the systems illustrated the adaptive filter 32 need cater for only a very much smaller number of samples, typically 30 to 60 samples.

CLAIMS

1. A method of attenuating in a mixed signal that part of an unwanted signal which is included in the mixed signal, comprising the steps of:

measuring the time offset between the unwanted signal and its contribution in the mixed signal,

inserting a compensating delay so as to co-time approximately the unwanted signal and its contribution in the mixed signal, and

filtering the unwanted signal and removing it from the mixed signal, by using an adaptive signal cancellation circuit.

2. A method according to claim 1, in which the mixed signal and the unwanted signal are first filtered to remove signals outside the frequency band of interest.

3. A method according to claim 1 or 2, in which the signal is split into a plurality of frequency bands, and the frequency bands are processed independently by separate adaptive cancellation circuits prior to being recombined to form the processed signal.

4. A method according to claim 1, 2 or 3, in which the time offset measurement is used to adjust the coefficients of the adaptive cancellation circuit in order to ensure that the canceller remains within its operating range.

5. A method according to any of claims 1 to 4, in which the measurement of the time offset comprises comparing the mixed signal with a signal containing the unwanted signal.

6. Apparatus for attenuating that part of an unwanted signal which is included in a mixed signal, comprising:

means for measuring the time offset between the unwanted signal and its contribution in the mixed signal,

compensating delay means controlled by the output of the measuring means so as to co-time approximately the unwanted signal and its contribution in the mixed signal, and

an adaptive signal cancellation circuit for filtering the unwanted signal and for removing it from the mixed signal.

7. Apparatus according to claim 6, including filter means for filtering the mixed signal and the unwanted signal to remove signals outside the frequency band of interest.

8. Apparatus according to claim 6 or 7, in which the signal is split into a plurality of frequency bands and the frequency bands are processed independently by separate adaptive cancellers prior to being recombined to form the processed signal.

9. Apparatus according to claim 6, 7 or 8, in which the time offset measurement means adjusts the coefficients of the adaptive cancellation circuit in order to ensure that the canceller remains within its operating range.

10. Apparatus according to any of claims 6 to 9, in which the time offset measurement means comprises means for comparing the mixed signal with a signal containing the unwanted signal.

11. A method of attenuating in a mixed audio signal that part of an unwanted audio signal which is included in the mixed signal, substantially as herein described with reference to Figures 1 to 4 of the drawings.

12. A method of attenuating in a mixed audio signal that part of an unwanted audio signal which is included in the mixed signal substantially as herein described with reference to Figure 5 of the drawings.

13. Apparatus for attenuating that part of an unwanted signal which is included in a mixed signal, substantially as herein described with reference to Figures 1 to 4 of the drawings.

14. Apparatus for attenuating that part of an unwanted signal which is included in a mixed signal, substantially as herein described with reference to Figure 5 of the drawings.

Patents Act 1977

Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

GB 9317050.4

Relevant Technical fields

(i) UK Cl (Edition L) H4R: RD; RLAS; RLS
H4L: LFND

(ii) Int Cl (Edition 5) H04B

Databases (see over)

(i) UK Patent Office

(ii) ONLINE: WPI

Search Examiner

AL STRAYTON

Date of Search

30 SEPTEMBER 1993

Documents considered relevant following a search in respect of claims ALL

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

SF2(p) AT - doc99\fil001072

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